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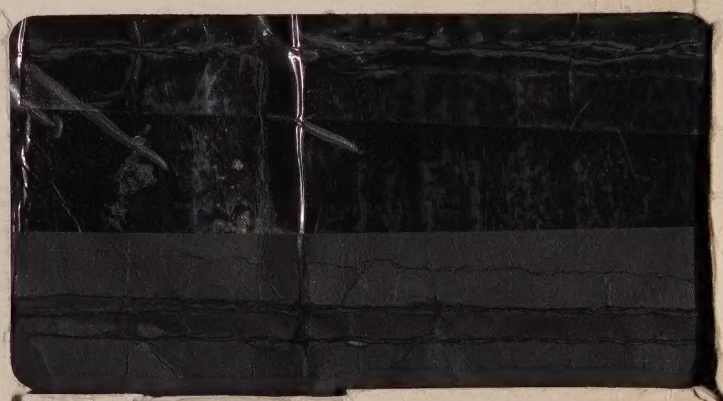
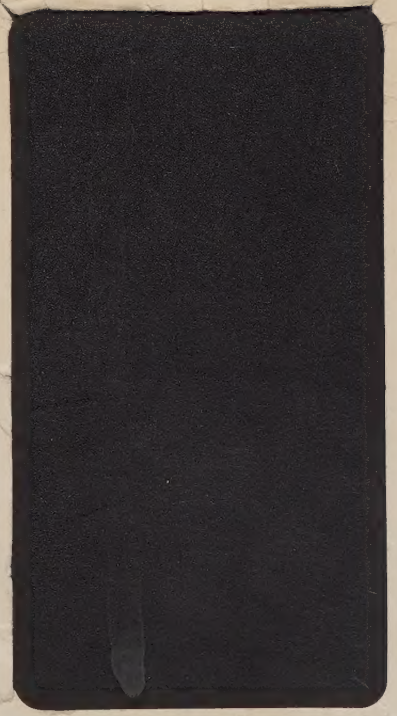


INSTRUMENTATION

KEITHLEY INSTRUMENTS



STANDARDS LAB.

INSTRUCTION MANUAL

# MODEL 610A, 610R

MULTI-PURPOSE ELECTROMETER
AND ACCESSORIES

# TABLE OF CONTENTS


| Title | Page |
|---|---|
| Section I. Introduction. | .1-1 |
| Section II. Specifications and Description | .2-1 |
| Specifications | .2-1 |
| Description. | .2-2 |
| Section III. Circuit Description | .3-1 |
| Voltmeter. | .3-1 |
| Ammeter. | .3-3 |
| Ohmmeter | .3-4 |
| Standard Resistance Check... | .3-7 |
| The Regulated Power Supplies | .3-7 |
| Section IV. Operation. | .4-1 |
| Preparing the Instrument for Operation | .4-1 |
| Measuring Voltage. | .4-1 |
| Measuring Current. | .4-2 |
| Measuring Resistance | .4-2 |
| Internal Resistor Check. | .4-4 |
| Internal Voltage Check | .4-4 |
| Using External Indicators. | .4-4 |
| Miscellaneous Applications | .4-5 |
| Zero Center Operation. | .4-6 |
| Section V. Accessories | .5-1 |
| Section VI. Maintenance. | .6-1 |
| Trouble Shooting | .6-1 |
| Recalibrating Power Supplies | .6-2 |
| Replaceable Parts List | .6-5 |
| Voltage and Resistance Chart | .6-9 |
| Schematic Diagram. | .6-11 |
| *Change Notice. | .Last Page |


*If a change in the instrument affects the instructions, the correction is printed on a yellow sheet at the back of the manual.

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# SECTION I - INTRODUCTION

The Keithley Model 610A Electrometer is an ultra-high impedance voltmeter with full-scale ranges of 0.01, 0.03, 0.10, 0.30, 1.0, 3.0, 10, 30, and 100 volts. Accuracy is within 2% of full scale on all ranges.

The maximum input resistance is greater than $10^{14}$ ohms; in addition, the input resistance may be varied in decade steps from one ohm to $10^{11}$ ohms by means of the shunt resistors built into the instrument. Thus, the 610A is not only appropriate for measurement in high-impedance circuits, but also can be used where a high input impedance would merely introduce unwanted pickup.

The 610A may be used as a direct-reading ammeter from 3 amperes to $10^{-13}$ ampere full scale. This 14-decade range is covered in overlapping 3x and 10x scales. Accuracy is within 3% of full scale from 3 amperes to $10^{-10}$ ampere, and 4% of full scale from $3 \times 10^{-9}$ to $10^{-13}$ ampere.

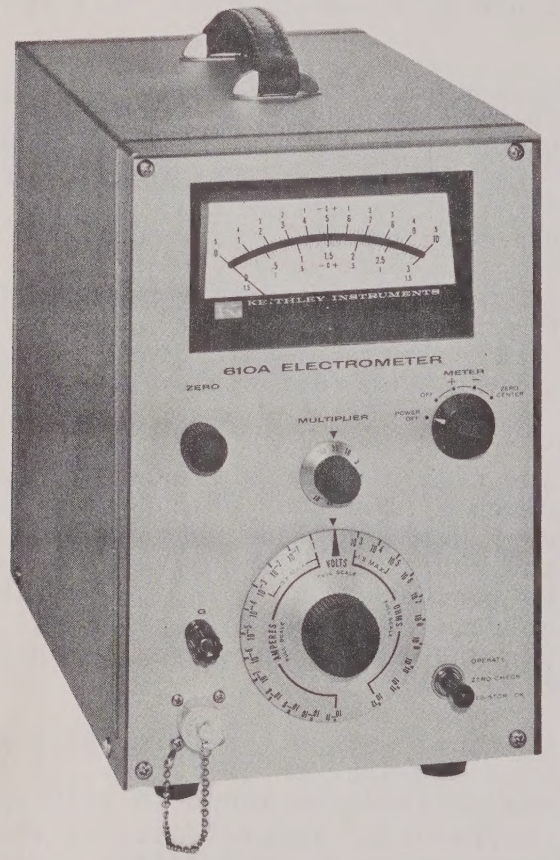
Two current measuring methods are available to the user of the 610A. They are selected by a slide switch at the back of the instrument. Normally, current is determined by measuring the voltage drop across a resistor shunted from input to ground. Alternately, on the $10^{-4}$ to $10^{-13}$ ampere ranges, negative feedback can be applied to the input of the voltmeter through the current measuring resistor. This largely eliminates the input drop and increases measuring speed, particularly on the more sensitive ranges.

The 610A measures 0.2 ohm to $10^{11}$ ohms with a two-terminal input. With a guarded input, its range is extended to $10^{14}$ ohms. A 1000-volt external supply would further extend the range to $10^{16}$ ohms. Unlike conventional ohmmeters, information is presented on the same linear scales used for current and voltage readings. Accuracy is within 3% of full scale up to $3 \times 10^{8}$ ohms, within 5% beyond.

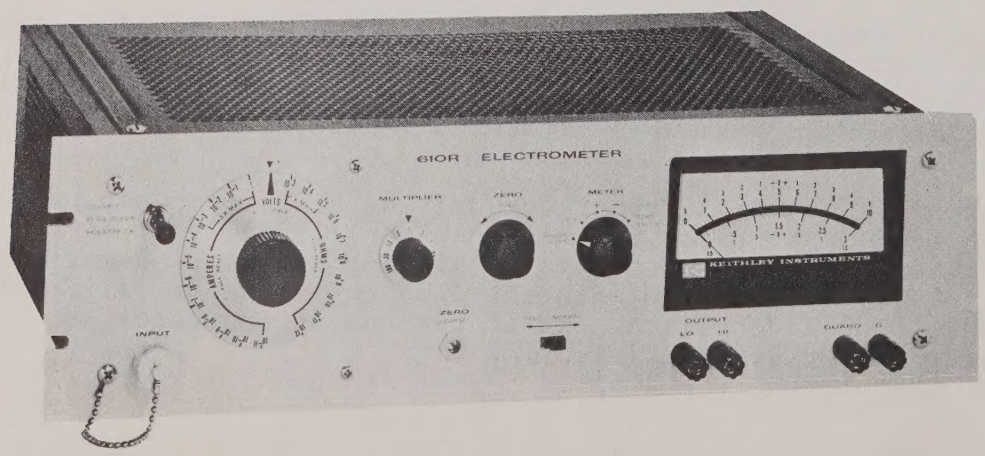
As a dc preamplifier, the 610A has a maximum gain of 1000, obtainable in 9 steps of 0.1, 0.3, 1, 3, 10, 30, 100, 300, and 1000. Gain accuracy is within 1% on all gain steps. The continuing stability of the gain is assured by a feedback factor in excess of 100 on any range.

The output is either 10 volts for driving high impedance devices such as oscilloscopes or pen recorder amplifiers, or 1 ma for driving low impedance recorders or similar devices. A calibration potentiometer is provided with the 1 ma position for calibrating recorders. A slide switch next to the output connector permits selecting the desired output.

Red meter scales and a ZERO CENTER position on the METER switch permit all of the above operations with the zero reference at the center of the meter dial rather than at the left.




The Model 610A (left) and the Model 610R (below) have identical electrical specifications and performances. The two models differ only in physical appearance; the 610A is for bench use while the 610R is for rack mounting.



# SECTION II - SPECIFICATIONS & DESCRIPTION

## SPECIFICATIONS

Ranges:

a. Voltage: 0.01, 0.03, 0.1, 0.3, 1, 3, 10, 30, and 100 volts full scale.

b. Current: 3 amperes to $10^{-13}$ amperes full scale in 1x and 3x overlapping ranges.

c. Ohms: 10 ohms to $10^{14}$ ohms full scale on linear 1x and 3x overlapping ranges.

d. Meter scales: Black - Left zero, 0 to 3 and 0 to 10
Red - Center zero, -1.5 to 0 to +1.5 and -5 to 0 to +5.

Accuracy:

a. Voltage: 2% of full scale on all ranges.

b. Current: 3% of full scale from 3 amperes to $10^{-10}$ amperes. 4% of full scale from 3 x $10^{-10}$ to $10^{-13}$ amperes.

c. Ohms: 3% of full scale from 10 ohms to $10^{10}$ ohms. 5% of full scale from 3 x $10^{10}$ ohms to $10^{14}$ ohms.

Resistance Standards:

1, 10, 100, 1000, $10^4$, $10^5$, $10^6$, $10^7$, $10^8$ ohms, 1% accuracy; $10^9$, $10^{10}$, and $10^{11}$ ohms, 2% accuracy.
The $10^9$ and $10^{10}$ ohm and $10^{11}$ resistors may be expected to change slightly in value with age.

Input Impedance:

On the VOLTS position the input impedance is greater than $10^{14}$ ohms resistive, shunted by approximately 30 micromicrofarads.

Drift:

Less than 2 millivolts per hour after a 1 hour warm-up.

Recorder Output:

1 milliampere or 10 volts for full scale meter deflection, selected by a rear panel switch.

Amplifier:

Frequency response is DC to 500 cycles on the most sensitive range, rising to 10 kc on the least sensitive range. Maximum gain is 1000. Noise is less than 3% (peak to peak) of full scale.

Line Regulation:

A ten percent change in line voltage in the range of 100 to 130 or 200 to 260 volts will cause a change of less than 2 millivolts equivalent input.

Tubes:
Two 5886, two EF86, one 6BH8, two 12AX7, one 12B4A, one 0G3, one 0A2, one 0B2.

Cabinet:
7-1/4 wide by 11-1/2 high by 13-3/4 deep. Weight 21-1/4 lbs.

Power Supply:
100 to 130 (or 200 to 260) volts, 50 to 60 cycles at approximately 50 watts.

## DESCRIPTION

The Keithley Model 610A is a line operated multipurpose dc measuring instrument of extremely wide range. The measuring ranges are summarized below:

VOLTAGE: 10 millivolts to 100 volts full scale. The input impedance is greater than $10^{14}$ ohms shunted by approximately 30 micromicrofarads on the VOLTS position of the RANGE SWITCH. The input resistance may be varied from $10^{11}$ ohms to 1 ohm in decade steps by rotating the RANGE switch in the AMPERES range marking.

HIGH VOLTAGE WITH ACCESSORIES: The Model 6102A 10:1 divider probe. extends the measuring range to 1000 volts. The divider resistance is $10^{10}$ ohms and its division accuracy is 1%.

The Model 6103A 1000:1 divider probe extends the measuring range to 30 KV. Its input resistance is $10^{12}$ ohms and its division accuracy is 3%.

CURRENT: 3 amperes to $10^{-13}$ amperes full scale. From 3 amperes to $3 \times 10^{-3}$ amperes the current is measured by measuring the drop across a resistor shunted across the input. From $10^{-4}$ to $10^{-13}$ amperes, the method above may be used or, by placing the FAST-NORMAL switch on the back panel in the FAST position, negative feedback is applied around the shunt resistor. This makes the input drop negligible and improves speed of response considerably on the low current ranges.

OHMS: 10 ohms to $10^{14}$ ohms full scale.

The linear ohms scale is achieved by measuring the unknown resistor with a known, constant current flowing through it. The voltage drop across the sample is then proportional to the resistance. Resistance from 10 ohms to $10^{11}$ ohms full scale is measured by a two terminal method. From $10^{11}$ to $10^{14}$ ohms, use of the GUARD terminal available at the rear of the instrument is recommended.

DC AMPLIFIER: The frequency response of the Model 610A as an amplifier is from dc to 500 cycles on the 100 millivolt range rising to 10 kc on the 100 volt range. The output is either 10 volts or 1

milliampere for full scale meter deflection. In the NORMAL micro-microammeter position, one side of the output is grounded. For directions pertaining to the use of recorders see Section IV-G.

CURRENT SOURCE: When measuring ohms, the instrument is designed to supply a constant current to any device placed across its input terminals. The magnitude of the current is equal to the reciprocal of the designation on the OHMS segment of the RANGE switch. Therefore, the instrument may be used as a current source for calibration of other instruments if desired.

CONTROLS AND TERMINALS: The input connector is Gremar Type #6804. The mating connector is supplied as well as an accessory binding post which plugs into the center of the connector. A ground binding post is mounted on the panel above the input connector.

Front Panel controls are:

RANGE switch, located in the center of the front panel under the meter. This control selects VOLTS, OHMS, or AMPERES. On the AMPERES position, a shunt resistor whose value is the reciprocal of the designated range may be used to decrease the input resistance as well as to measure current.

MULTIPLIER switch, located in the center directly under the meter, determines the voltage sensitivity of the dc amplifier, and sets the voltage range when the RANGE is set on VOLTS. On OHMS or AMPERES, the setting of this knob multiplied by the OHMS or AMPERES setting gives the full scale meter range.

ZERO control, located to the left of the MULTIPLIER switch under the meter, is used to set the meter to zero.

METER switch, at the right under the meter, turns the instrument on, determines meter polarity, and permits zero center operation.

OPERATE switch, located at the bottom right, selects normal operation or one of the two check positions.

In the ZERO CHECK position, the input terminals are shorted through 1 megohm, while the amplifier input is shorted. In the RES CHECK position, the internal high megohm resistance standards are measured.

Rear Panel controls are:

FUSE, at the upper right. With 117 volt AC power use 1.5 ampere fuse; with 230 volt power use 1 amp fuse.

POWER INPUT. Unless indicated, instrument is wired for 117 volts 50-60 cps. For 230 volt operation, consult the circuit schematic diagram.

RECORDER CAL. Used to calibrate 1 ma. recorders, so their scale corresponds with the panel meter.

1 MA - 10V. In the 1 MA position, OUTPUT will drive 1 milliampere recorders. In the 10V position, the output is 10 volts for full scale panel meter deflection.

OUTPUT connector for external recorders.

NORMAL-FAST. This control is locked in NORMAL position. In FAST position, current measurements are made with feedback around the shunt resistor. On OHMS, the FAST position is used when the INPUT GUARD terminal is used.

INPUT GUARD. With the NORMAL-FAST switch on FAST, the low impedance end of the test sample is returned to this terminal when it is desired to measure the resistance of a guarded sample.

COARSE ZERO. If the amplifier is quite badly unbalanced, the COARSE ZERO switch is used to bring the front panel ZERO control in range.

# SECTION III - CIRCUIT DISCUSSION

The basic element of the Model 610A is a highly accurate, stable dc voltmeter with a full scale sensitivity of 10 millivolts and an input impedance greater than $10^{14}$ ohms shunted by 30 micro-microfarads. Amperes and ohms are measured by the use of resistance standards. The various connections necessary for amperes and ohms measurements will be discussed following the detailed description of the amplifier.

## A. VOLTMETER

Refer to DR 11861 D at the rear of the manual.

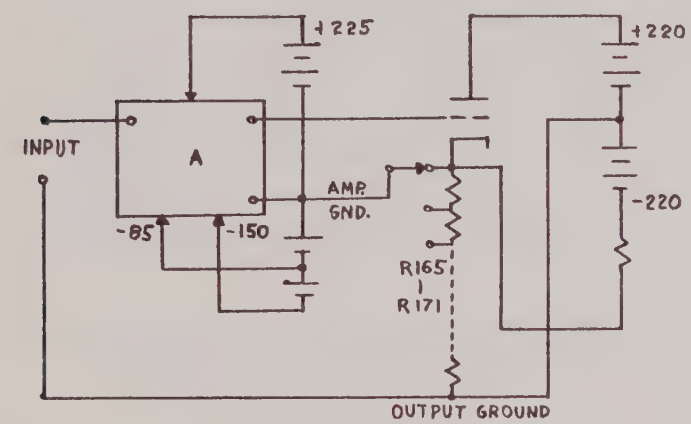



FIGURE 610-1

The amplifier proper consists of V1 through V5-A. V5-B is a Cathode follower which drives the amplifier at the same instantaneous potential as the input signal. In other words the neutral or ground terminal of the amplifier is not grounded to the chassis but is attached either directly or through divider R165 through R171 to the output cathode follower. Fig. 610-1 shows this diagramatically. The amplifier A is driven by the cathode follower. If it is desired to have unity gain, the amplifier is connected directly to the cathode. To increase the voltage gain, a fraction of the output voltage rather than all of it is fed back.

The purpose of this arrangement is to allow the input to accept relatively large input voltages without use of input dividers, which are neither stable nor accurate at high impedance. Consequently, the Model 610A will accept 100 volts without the use of input dividers, preserving the high input impedance and accuracy of the amplifier. Accessory probes are available for extending the voltage range at reduced input resistance and accuracy.

Since the amplifier proper is driven by the cathode follower, the plus and minus 220 volt supplies for the cathode follower are referred to input ground while the +225 volt and the -85 and -150 volt supplies for the amplifier are referred to amplifier ground which is "floating". In subsequent discussion, reference will be made to the amplifier ground as "floating ground" and to cathode follower ground as "output ground".

The amplifier input consists of two balanced 5886 electrometer tubes. The filaments are operated in parallel through a dropping resistor from the regulated B-plus supply. The control grid of V1, the active electrometer tube, is protected by R123, a ten megohm resistor, bypassed for high frequencies by C101. The control grid of V2, the "dummy" tube, is returned to floating ground. The input switch, SW3, connects the grid of V1 to the input terminal on the OPERATE position and connects it to ground, through the 1 megohm protective resistor, on ZERO CHECK.

The screen grids of V1 and V2 are returned, in effect, to the cathodes of V3 and V4 through SW4 (COARSE BALANCE) and R180 (ZERO). The balance controls function by adjusting the dc voltages of the electrometer tube screens. Since the cathode of V3 and V4 are free to move, the result is that a negative feedback loop for signals in phase at the electrometer tubes exists through the cathode circuit of V3 and V4 back to the screens of V1 and V2. This connection stabilizes the plate potential of the input tubes, and causes the first stage gain to be much greater for signals arriving at the active tube control grid than spurious signals at both electrometer tubes, such as variation in the plate supply and changes in transconductance due to filament temperature changes. Also due to this stabilization, electrometer tube operating points are maintained even though 10 meg plate load resistors are used to assure a large voltage gain in this stage. This obviates the need for regulation of the filaments of subsequent stages.

V3 and V4 form an ordinary differential amplifier and their output is taken single ended into V5-A. V6-A drives the output cathode follower.

The voltmeter sensitivity is determined by the fraction of the cathode follower voltage fed back via the divider, R165 through R171. 10 volts appears at the V5-B cathode for full scale meter deflection for the ranges from 10 millivolts through 10 volts. On the 30 and 100 volt ranges, 30 and 100 volts respectively are fed directly back to floating ground. R161 is the meter multiplier resistor from 10 millivolts to 10 volts. On the 30 and 100 volt ranges, R162 and R163 are used.

The OUTPUT is derived directly from the 6BH8 cathode except on the 30 and 100 volt ranges, where R158 and R159 are interposed. If the output switch is set at 10 V, R158 and R159 form a divider with R177 to attenuate the output to 10 volts. If the output switch is set at 1 ma, these resistors in combination with R164 and R160 are used to provide enough series resistance so that 1 milliampere flows into the recorder terminals. R164 and R160 calibrate the recorder on all ranges.

The feedback loop is stabilized against oscillation by C102 and C103 together with R172 through R176. Insertion of R172 through R176 in the cathode of V5-A, or the omission of a resistor by the range switch, determines the loop gain. The gain is kept high enough so that there is a feedback factor of at least 100 on all ranges, but the gain is not allowed to become high enough to cause oscilla-

tion. C102 and C103 provide a 6 db per octave dominant lag cut-off characteristic.

B. AMMETER

Grid current of the input electrometer tube fixes the minimum current that may be measured. The Model 610A grid current will usually be less than $2 \times 10^{-14}$ amperes. On low current ranges, the grid current will be apparent and may be balanced out with the ZERO control or subtracted from the final reading.

(1) Shunt Resistor Method (NORMAL)

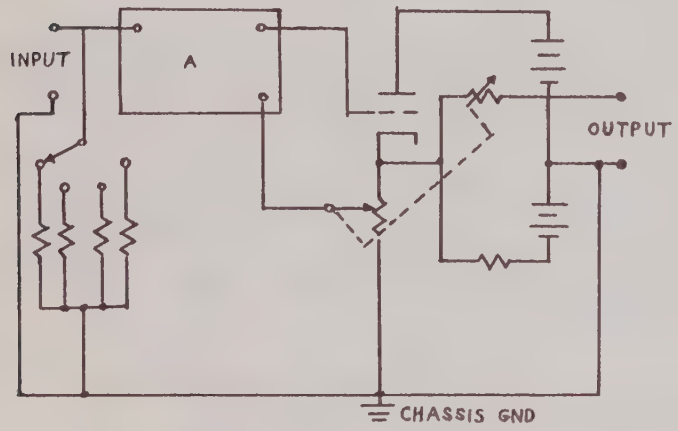



FIGURE 610-2A

In the normal operating connection as shown in Fig. 610-2A, current is measured by placing a resistor across the input terminals and measuring the voltage drop. Currents from 3 amperes to $10^{-13}$ amperes may be measured by this method since the range switch selects resistors ranging from one ohm to $10^{11}$ ohms in decade steps. The voltage drop is selected by the MULTIPLIER switch; the setting is the input voltage drop for full-scale meter deflection.

(2) Feedback Method (FAST)

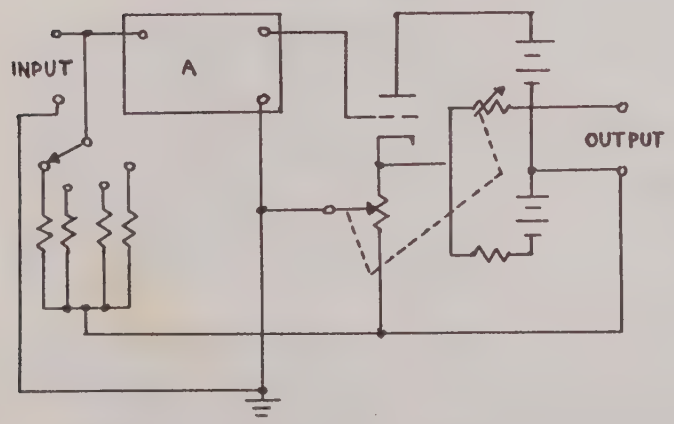



FIGURE 610-2B

In the voltmeter discussion above, floating ground has been driven by the cathode follower and output ground has been connected to the low impedance side of the input connector. In the FAST connection, shown in Fig. 610-2B, the amplifier ground is connected to the low impedance side of the input; the cathode follower ground floats, and negative feedback is applied through the shunt resistor.

In the Model 610A, it is possible to use this connection with currents of 100 microamperes or less. To change the connection, remove the lock from the NORMAL-FAST switch at the bottom of the rear panel and change it to the FAST position. The advantages of this connection are:

a. The effect of input capacity is largely neutralized, that is, the time constant of the input and cable capacity and the shunt resistor used will be decreased at least 100 times as compared to the NORMAL connection, corresponding to a 100-fold increase in response speed.

b. The input drop will be reduced at least 100 times.

If Fig. 610-2B is again consulted, it will be seen that this connection converts the 610A into an operational amplifier with a resistor from the output to the input. Therefore, the following cautions apply:

a. The input cannot be shorted since this will remove the feedback.

b. The internal impedance of the current source being measured should not be less than about one-tenth of the value of the feedback resistor used for measurement.

c. This connection should not be used for measuring the leakage current of capacitors since the connection of a capacitor to the input causes the circuit to be transformed into a differentiator with the resultant extreme sensitivity to very small voltage transients. For this measurement the NORMAL should be used.

d. Do not attempt to use the FAST connection for currents exceeding 100 microamperes.

C. OHMMETER

1. Two Terminal Method

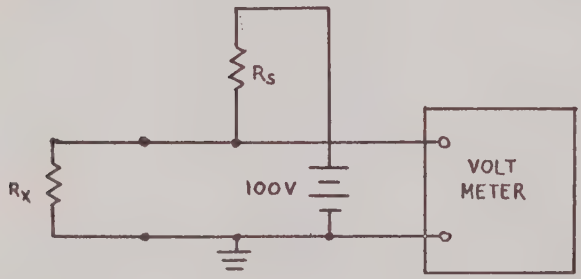



FIGURE 610-3

The Model 610A employs a linear scale to provide a megohmmeter of high accuracy. The linear ohms scale is achieved by supplying a constant current to the sample and measuring the voltage drop across it. One method is shown in Fig. 610-3.

The constant current source can consist of a high voltage and a large resistor of known value. As long as the drop across the unknown resistor is of the order of 1% of the total voltage, the current can be considered constant. In the Model 610A on the $10^3$ and $10^4$ ranges, the current is supplied in this manner from a 100 volt supply with the appropriate dropping resistor as illustrated in Fig. 610-3. For example, with a current of one milliampere, the voltage drop across a one ohm resistor will be one millivolt. Thus, this value can be read on the 10 millivolt range of the 610A.

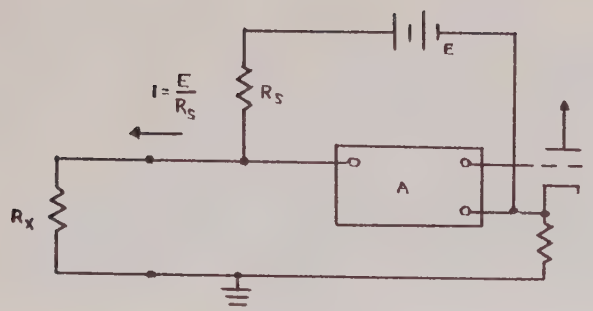



FIGURE 610-4

On the $10^5$ range and higher, a second method is used to obtain a constant current. This is illustrated in Fig. 610-4. The ground connections are in the NORMAL position, that is, the amplifier ground is driven and the cathode-follower ground is attached to the input ground. The voltage source is only one volt. However, it is attached between floating ground and the grid of the voltmeter while, as before, the test sample is attached between input ground and the voltmeter grid. Since feedback to the amplifier ground keeps it at virtually the same potential as the input grid regardless of the input voltage, the voltage across the current source resistor cannot change. Therefore, this arrangement provides a true source regardless of the input voltage. Thus, resistances may be measured using any voltmeter range on the $10^5$ to $10^{12}$ ohmmeter ranges as opposed to the limit of 1 volt maximum on the $10^3$ to $10^4$ ohmmeter ranges.

2. Ohms measurement using GUARD terminal

There are two disadvantages with the method just outlined:

a. When measuring resistances greater than $10^{11}$ ohms, input capacity causes the meter reading to be annoyingly slow.

b. If it is desired to use large voltages across the sample, this same voltage will appear across the input insulation of the electrometer and the input insulation will contribute error to the reading because of the current also flowing in it.

For these reasons a second connection for measuring ohms is provided.

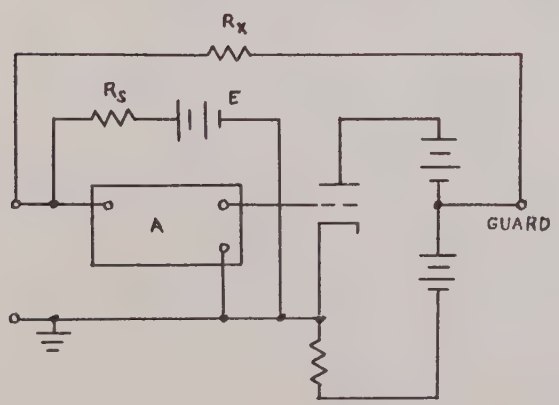



FIGURE 610-5

The switch at the rear of the instrument is moved from NORMAL to FAST and the low impedance end of the resistance sample is connected to the GUARD terminal. Fig. 610-5 shows the arrangement. Now, as with measuring amperes with the FAST method, the amplifier ground is attached to the input ground and the cathode-follower ground is floating. The result is that feedback is applied through the unknown resistance to reduce the slowing effect of

instrument input capacity. Also, since the potential across the input terminal is small, the leakage error is reduced.

3. Use of External Voltage Supply

With the constant current method of measuring resistance, the voltage across the unknown may not be arbitrarily selected, and the time of measuring capacitor leakage tends to be long, since constant-current charging is slower than the exponential charge available with an RC circuit.

Due to these facts, it may be desirable to use an external voltage supply and measure the leakage current on the AMPERES scale (NORMAL operation).

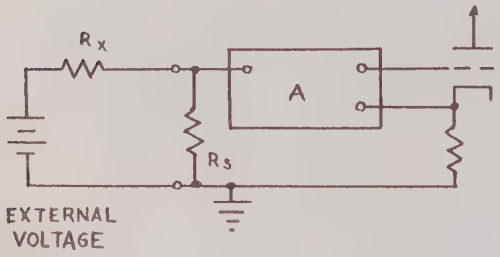



FIGURE 610-6

The unknown is connected between the input terminal of the electrometer and the source of voltage. This is shown in Fig. 610-6. If the applied voltage is large compared to the voltage drop across the electrometer (so that the voltage across the sample is substantially the applied voltage) the resistance is simply equal to the voltage applied divided by the current measured. If the voltage drop is an appreciable fraction of the applied voltage, the resistance equals the voltage applied minus the input drop divided by the current measured. It will be rarely necessary to correct for the input drop of the electrometer due to the excellent voltage sensitivity of the Model 610A.

It is advisable to use the NORMAL micro-microammeter connection for the measurement of leakage resistance of capacitors in this manner, since instability is likely to occur using the FAST connection. However, in cases where the capacity shunted across the sample is small, it will be possible to realize a considerable increase in speed of response by utilizing the FAST connection.

Some precaustions are recommended when testing capacitors. Be sure that capacitors have discharged before removing from test circuit. With the 610A input switch on ZERO CHECK, the input is shorted to ground through 1 megohm, providing a discharge path for the capacitor. The reading time may be shortened if the capacitor is allowed to charge through a low impedance position on the AMPERE switch before the appropriate measuring resistor is inserted in the circuit.

It should be further noted that capacitor measurement is likely to be a slow process in any case due to the fact that it may take considerable time for the molecular orientation of the dielectric to take place at the testing potential. It may take minutes or even hours in some cases to achieve a stable reading.

## D. STANDARD RESISTOR CHECK

The resistance standards used in the Model 610A have been described in the specification section. In general the resistors from 1 ohm to $10^8$ ohms can be expected to retain a 1% accuracy throughout the life of the instrument. The high megohm resistors are correct to 2% when installed, and will usually be between 1% and 2% above the nominal value. Since they always decrease in value with time, they are likely to remain within specifications for three to six years after the instrument is delivered.

However, to determine the accuracy of these resistors, a resistance check position is provided on the input switch.

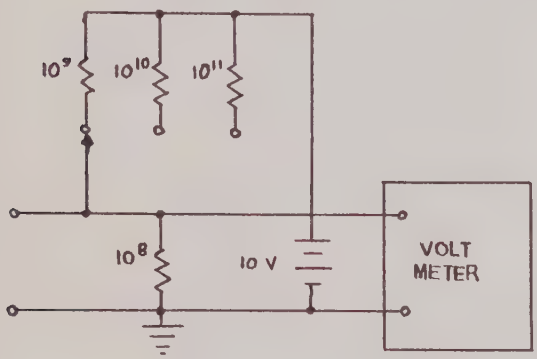



FIGURE 610-7

The method used in checking the resistors is outlined in Fig. 610-7. The ohmmeter is used in the standard manner except that the input switch is turned to RES CHECK. In this position a 1% $10^8$ ohm resistor is placed across the input. In turn, $10^9$, $10^{10}$, and $10^{11}$ ohm resistors are used to supply current through this resistor from 10 volts. Thus, if the $10^{11}$ position on the OHMS segment of the RANGE switch is used, the meter should read full scale on the .01 position of the MULTIPLIER. Correspondingly, the reading is full scale on the 0.1 position for the $10^{10}$ ohm resistor and the 1.0 position for the $10^9$ ohm resistor.

## E. THE REGULATED POWER SUPPLIES

The negative regulator consists of cascaded voltage regulator tubes V11 and V10. This combination provides a well-regulated supply for the negative return of the second amplifier stage and reference for the positive supply. The maximum current supplied by this regulator combination is about 2.5 milliamperes so that the regulator tubes are able to operate satisfactorily over the 100 to 130 volt range of line voltage. V11, type 0A2, supplies a minus 150 volt potential for the amplifier interstage dividers.

The positive 225 volt regulator is a three tube regular circuit consisting of V8, the series tube, and V6 and V7 which form the feedback amplifier. This circuit operates satisfactorily from 100 to 130 volts and is largely responsible for the extreme freedom from line transients which the Model 610A exhibits.

# SECTION IV - OPERATION

## A. PREPARING THE INSTRUMENT FOR OPERATION

1. Connect to power line of proper voltage and frequency. Unless otherwise indicated at rear of instrument, the Model 610A is wired for 100 to 130 volts 50 to 60 cps. If it is desired to operate on 200 to 260 volts 50 to 60 cps, consult DR 11861 D at rear of the manual for instructions.

2. Set controls as follows:

   MULTIPLIER: 100
   RANGE SWITCH: VOLTS
   OPERATE SWITCH: ZERO CHECK
   INPUT TERMINAL: Shield with cap.

3. Turn the METER switch to meter +. The instrument should come to zero in approximately 30 seconds. Final stability within drift specifications will not be achieved for 1 hour.

4. Rotate the MULTIPLIER switch toward the high sensitivity end, adjusting ZERO as required. If it is impossible to zero the meter with the front panel ZERO control, use COARSE BAL control on rear panel to bring the instrument within range of the ZERO control.

5. Connect leads as required for measurement. If high impedance is involved, the input should be shielded using a coaxial connection or shielded enclosure. The various accessories for the Model 610A may be used.

   If the impedance is low and leads can be kept short, the binding post adapter furnished with the instrument may be used.

   The Keithley Model 6101A Shielded Test Probe will suffice for most measurements.

## B. MEASURING VOLTAGE

Place RANGE switch at VOLTS. Turn MULTIPLIER switch to expected sensitivity and check meter zero. Move OPERATE switch up to OPERATE and read. If the sensitivity of the instrument is increased, recheck the zero setting.

For voltages greater than 100 volts, use the Model 6102A 10:1 Divider Probe, or the Model 6103A 1000:1 Divider Probe and measure as above.

C. MEASURING CURRENT

1. NORMAL method (3 amperes to $10^{-13}$ amperes full scale).

Turn RANGE switch to desired AMPERES range. Make sure the switch at the rear of the instrument is on the NORMAL position. Connect current source to input. The product of the reading on the RANGE switch and the MULTIPLIER gives the full scale range. Check zero first with OPERATE switch and then read unknown current. The full scale voltage drop across the instrument is the setting of the MULTIPLIER.

2. FAST method ($10^{-4}$ to $10^{-13}$ amperes full scale).

Proceed as above, except move the FAST-NORMAL switch at the rear of the instrument to the FAST position. The input drop is now negligible and the speed of response is increased approximately 100 times. However, observe the following cautions:

a. Use only the input switch to check zero; DO NOT SHORT INPUT.

b. The low side of the output is no longer grounded.

Therefore, if the instrument is being used with an output recorder the recorder must not be grounded to the case of the 610A.

c. Do not use this position for the measurement of capacitor leakages.

D. MEASURING RESISTANCE

1. NORMAL method (10 ohms to $10^{11}$ ohms full scale).

Turn RANGE switch to desired OHMS range. Make sure that NORMAL-FAST switch is in the NORMAL position.

Connect resistance sample to be measured only after OPERATE switch has been moved to ZERO CHECK. Do not open-circuit instrument when on OHMS, since the input will develop a large voltage due to its constant current characteristic. However, if the sample is first connected and then the OPERATE switch is moved to OPERATE, the full scale input voltage will be the setting of the MULTIPLIER.

Before reading OHMS, turn RANGE switch to the approximate range of the unknown resistance. By manipulating the MULTIPLIER and the RANGE switch, the sample can be tested at a number of test potentials, if desired.

The full-scale ohms range is the RANGE switch setting times the MULTIPLIER.

This two terminal method is the simplest and will work quite satisfactorily up to about $10^{11}$ ohms. At resistances greater than $10^{11}$ ohms, it is desirable to employ a GUARD connection both to speed up the response of the instrument and to nullify the error of leakage across the electrometer input insulation.

2. GUARDED method ($10^{11}$ to $10^{14}$ ohms full scale).

Proceed as with the two terminal method with the exception that the sample is connected between the INPUT terminal and the GUARD terminal on the rear panel, the FAST-NORMAL switch must be set at FAST.

3. EXTERNAL VOLTAGE method.

Any external voltage may be used.

The unknown is connected between the test potential and the INPUT terminal of the electrometer. The current is then measured, using the NORMAL or FAST method, and the resistance calculated.

Proceed as follows:

a. Turn input switch to ZERO CHECK.

b. Connect unknown between INPUT terminal and source of potential. A switch should be connected in the high voltage line so that when the sample is disconnected from the potential, the low impedance end of the sample is grounded.

c. FAST-NORMAL switch should be at NORMAL.

d. Apply potential to sample before switching to OPERATE. Start the RANGE switch at low current sensitivities and advance the sensitivity until a reading is obtained.

If the potential applied is at least 100 times the full scale ammeter drop (MULTIPLIER setting), the resistance is equal to:

$$\frac{\text{POTENTIAL APPLIED}}{\text{CURRENT READING}}$$

If the potential applied is not large compared to the ammeter drop, the resistance is equal to:

$$\frac{\text{POTENTIAL APPLIED - INPUT DROP (VOLTS)}}{\text{CURRENT READING}}$$

e. If it is possible to operate on FAST micro-microammeter, the input drop need not be considered in the calculation.

E. INTERNAL RESISTOR CHECK

1. To check $10^9$: Move input switch to ZERO CHECK, RANGE switch to OHMS x $10^9$. Turn MULTIPLIER to 1.0 or 3.0. Move input switch to RES CHECK. If reading is exactly one volt, resistor is 1.00 x $10^9$.

2. To check $10^{10}$: Turn MULTIPLIER to .1 or .3. Reading should be .1 volt.

3. To check $10^{11}$: Turn MULTIPLIER to .01 or .03. Reading should be .01 volts.

F. INTERNAL VOLTAGE CHECK

The internal 225-volt and 100-volt supplies are used to test resistance samples and therefore, should be checked periodically.

To check these supplies see Section VI - MAINTENANCE.

G. USING EXTERNAL INDICATORS

The output of the Model 610A will drive one-millivampere recorders and servo rebalance recorders, as well as higher impedance instruments such as pen recorder amplifiers and oscilloscopes.

1. For use with one-milliampere instruments such as Esterline Angua, General Electric, and Texas Instrument Rectiriter: Connect to output connector at rear of instrument, pin 1 is the positive terminal. Place output switch at 1 MA position. Output is approximately 1 ma for full scale meter deflection on any range and can be made exactly 1.00 ma. Turn to a voltage range such as 100 millivolts full scale, where zero control has enough latitude, and adjust ZERO until panel meter reads full scale. Then adjust RECORDER CAL at the rear until the recorder also reads full scale. Next check the zero of the recorder and the panel meter and repeat full scale calibration. The meter polarity switch does not reverse the recorder output.

2. For use with servo rebalance recorders: On the 1 MA position, there is enough latitude in the RECORDER CAL pot so that even if the recorder terminals are short circuited, exactly 1 milliampere can be made to flow at full scale deflection of the panel meter. Therefore, for servo rebalance recorders, place a resistor across the output terminals equal to 1 ohm per millivolt of span and adjust RECORDER CAL to make sensitivity equal to full scale meter deflection. For example, with a 50 millivolt recorder place 50 ohms across output terminals before connecting recorder.

3. For use with oscilloscopes and pen recorder amplifiers, set output switch at the 10v position. Output is now 10 volts for full scale meter deflection on any range.

The frequency response is dc to 500 cycles on the 10 millivolt range rising to 10 kc on the 10, 30 and 100 volt ranges. The maximum amplitude which can be delivered by the amplifier is approximately 10 volts peak to peak. Maximum permissible load across the output terminals in this mode of operation is one megohm.

With the FAST-NORMAL switch at the rear of the instrument in the NORMAL position, the negative side of the output is grounded to the case of the instrument. However, in the FAST position neither side is grounded. Therefore, no difficulty will be experienced using oscilloscopes and pen amplifiers with the 610A in NORMAL operation. However, if it is desired to use the FAST position, care must be taken that there is no common ground between the pen writer or the oscilloscope and the Model 610A case.

## H. MISCELLANEOUS APPLICATIONS

CURRENT INTEGRATOR: The Model 610A may be used as an integrator for small currents such as cyclotron and mass spectrometer beam currents, since it is basically an operational amplifier with electrometer input when the FAST-NORMAL switch at the rear is placed in the FAST position.

To integrate current connect a polystyrene capacitor of suitable value between the GUARD terminal and the input. The RANGE switch is set at VOLTS so that there is no resistance placed across the capacity. Then if Fig. 610-2B is consulted, it can be seen that the standard resistor has been replaced by a capacitor and the 610A is now an integrator. The charge on the capacitor in coulombs is simply the product of the capacitor value chosen (in farads) and the setting of the MULTIPLIER switch (in volts). If it is desired that a time constant be introduced into the integrating circuit, the appropriate shunt resistor may be selected by the RANGE switch.

Practically it is suggested that the capacitor be enclosed in a grounded can. The connection to the GUARD terminal may be made by a simple unshielded lead. The connection to the input terminal should be made by means of a coaxial connection to one side of a "tee" adapter. The current input is made to the other side of the "tee".

The following procedure is suggested: Move input switch to ZERO CHECK, thus removing the charge from the capacitor and shorting the input. Zero if necessary. Return to OPERATE. If the integration is to take place over a long period of time, it is suggested that the instrument be used on the one volt range or higher so that zero drift and grid current will not be factors.

Move OPERATE switch to ZERO CHECK and RANGE switch to OHMS. The current that is supplied on each range is the reciprocal of the OHMS setting, and is not affected by the setting of the MULTIPLIER switch. However, for the current to be accurate, the amplifier should be in balance. It will be sufficient to balance the amplifier on the .1 volt position of the MULTIPLIER switch.

STATIC CHARGE MEASUREMENTS: The instrument is zeroed and the RANGE switch placed on VOLTS. The voltage sensitivity is perhaps placed at 10 or 30 volts full scale. The charged object is then brought near the uncovered, unshielded input connector of the 610A. Depending on the distance between the charge and the instrument, a voltage will be induced on the input terminals and can be read on the panel meter. The instrument zero should be checked frequently since accumulation of charge due to the electrometer tube grid current will cause a slow drift of input voltage.

Connecting a capacitor across the input reduces the drift due to grid current and also the sensitivity to charge. An electrode connected to the INPUT terminal which increases the capacitance between the INPUT terminal and the charged object will increase the sensitivity to charges.

## I. ZERO CENTER OPERATION

In some applications, such as null indication or in measuring voltages of either polarity near zero, it may be desirable to use the ZERO CENTER position on the METER switch. On this position, operation is just the same as for left-zero (normal), except that for zero input voltage or current, the meter pointer is at center scale.

The ZERO CENTER control on the inside chassis is used to set the meter pointer to zero for zero center operation. It should require only infrequent attention.

# SECTION V - ACCESSORIES

## MODEL 6101A ACCESSORY PROBE:

The Model 6101A probe consists of an input connector, 3 feet of low noise cable and a shielded probe head. Its purpose is to allow convenient connection to the electrometer input.

## MODEL 6102A - 10:1 DIVIDER PROBE:

The Model 6102A divider probe is intended for general purpose instruments where an extension of the upper voltage range of the 610A is desired. The division ratio is 10:1 correct to 1% and the probe input resistance is $10^{10}$ ohms. The probe is supplied with a mating connector and 3 feet of cable.

## MODEL 6103A - 1000:1 DIVIDER PROBE:

The Model 6103A probe is intended for very high voltage measurements at high impedance. The division ratio is 1000:1 correct to 3% and the probe input resistance is $10^{12}$ ohms. The probe is supplied with a mating connector and 3 feet of cable.

## MODEL 6104 TEST ADAPTER:

The Model 6104 Test Adapter is intended for use in making measurements wherein complete shielding of the component under test is required. External terminals are provided for either grounded tests, or a test requiring an external voltage source.

# SECTION VI - MAINTENANCE

No periodic maintenance is required other than checking the accuracy of the polarization potentials and the high megohm resistors as provided for by the front panel controls. There are no internal batteries. The method of performing these checks is outlined in Section IV part E and F.

The calibration of the voltmeter is set by R179 located on the vertical chassis carrying the majority of the tubes. This is set at the factory and should not require adjustment. If recalibration is performed, an accurate voltage source should be used.

## A. TROUBLE SHOOTING

The circuit is completely described in Section III. Study of that section will facilitate any trouble shooting.

The most usual trouble encountered is that on the most sensitive voltage range, with the input shorted, it is not possible to bring the meter pointer to zero. However, before assuming that the instrument is at fault make sure that resetting the COARSE BAL control at the rear of the instrument will not bring the instrument back into balance. If this does not work remove the instrument case and if necessary the bottom plate just below the input compartment to gain access to all circuitry. Follow this procedure:

1. Check for presence of regulated B-plus voltage by switching to meter + and checking at pin 6 of V-4 for +225V. If this voltage is not correct consult section following on servicing regulated power supply.

2. If correct voltage is present, check the plus and minus 220 volt supplies which supply the output cathode follower. The plus voltage is present on pin 3 of V5. The minus voltage may be obtained from the bottom of the 30K cathode resistor of V5-B. It is a 10 watt power resistor located on the metal chassis next to the rectifier stacks. If this voltage is not correct consult the schematic and trouble shoot the supply in the usual manner.

3. If no defects are found so far, proceed by shorting floating ground to output ground to remove the negative feedback. This is most conveniently accomplished by shorting the two ends of the FAST-NORMAL switch on the rear panel. In this condition the instrument will become very sensitive and in operating the ZERO control, the meter will be very difficult to hold on scale. However, the indication that the circuit is operating satisfactorily is that it is possible to swing the voltage through the correct operating point as indicated on the voltage-resistance diagram.

Now with the MULTIPLIER at .01 volts, proceed to check the operating points of the tube electrodes.

Regardless of the condition of the amplifier balance, the filament or cathode, and screen potentials should be reasonably close to the values on the circuit diagram. The plate and grid potentials will, however, depend on the setting of the ZERO control. However, if it is possible to swing the voltage through the correct value it may be assumed that the stage is working. Proceed in this manner until the point is found where the voltage cannot be swung through the value marked on the diagram. At this point it will be relatively easy to find the fault. First check the tube involved and then check the components.

Trouble shooting the regulated supplies:

1. Check the minus supply first since the positive supply is referenced to the negative supply. If the dc voltages seem correct and the trouble persists, check for excessive ripple which would indicate a bad rectifier or filter capacitor.

2. If the negative voltages are correct, then check the positive unregulated supply voltage in the same way.

3. If the above voltages are correct, check the tubes and components of the regulator circuit (V-6, V-7, V-8) for defects.

Miscellaneous troubles:

| Trouble | Cause | Remedy |
|---|---|---|
| Excessive grid current | Defective electrometer tube | Replace V1 and V2 with matched set |
| Excessive drift | Power supply not regulating | See section above |
| Excessive microphonics | Defective electrometer tube | Replace V1 and V2 with matched set |
| Instrument does not zero. | See section above | See section above |

The proper method of inserting electrometer tubes is shown in the voltage resistance diagram. When inserting do not touch the glass base where the leads emerge with the fingers.

B. RECALIBRATING POWER SUPPLIES

Three methods of calibrating the 100 volt and 225 volt supplies are possible.

1. This method is the least accurate since the error of the precision resistor used is added to the error of the instrument as stated on page II-1.

a. With the MULTIPLIER switch on 1 and RANGE switch on OHMS x $10^4$ connect a 10K precision resistor to the input. On OPERATE, the meter should be near full scale. If not, adjust the internal 100 volt control until a full scale reading is obtained.

b. For the 225 volt supply, the MULTIPLIER switch remains at 1 and RANGE switch is moved to OHMS x $10^5$. Now a precision 100K resistor is placed across the input and the 225 volt control adjusted until a full scale reading is obtained. To further check the 225 volt supply, check the $10^9$, $10^{10}$, and $10^{11}$ resistors as mentioned in Section IV-D to see if proper readings are obtained.

2. The next method requires the use of an accurate high impedance voltmeter, such as the Keithley Model 660 Guarded Differential Voltmeter, accuracy .02%. The accuracy of the 610A will then be the 610A specification value stated on page 2-1 plus .05%.

a. Place the RANGE switch on VOLTS, the MULTIPLIER switch on 1 and with the cover off, take a reading from the right terminal (two leads) of the 100 volt adjust pot to ground. If not at 100, set to 100.

b. For the 225 volt supply, a reading is taken at the junction of resistors R125 and R126, located in the input compartment just above the operate switch. At this point the voltage should be 1.0 volt. Use the Set 225 volt control to get 1 volt. The 225 voltage is a nominal reading, while the 1.0 volt calibration is taken from a voltage divider and should be accurately set.

3. The last and most accurate way is to send the instrument back to the factory for calibration. Here all the proper equipment is available to check and calibrate the Model 610A electrometer. Experienced technicians perform all work on the instruments to bring them within specifications.

| Circuit Desig. | Description | Part No. |
|---|---|---|
| C101 | Capacitor, ceramic disc, 100 mmf, 600 VDCW | C22-100 |
| C102 | Capacitor, ceramic disc, .0068 mfd, 600 VDCW | C22-.0068 |
| C103 | Capacitor, ceramic disc, .0068 mfd, 600 VDCW | C22-.0068 |
| C104 | Capacitor, ceramic disc, 100 mmf, 600 VDCW | C22-100 |
| C105 | Capacitor, ceramic disc, 100 mmf, 600 VDCW | C22-100 |
| C106 | Capacitor, ceramic disc, 47 mmf, 600 VDCW | C22-47 |
| C107 | Capacitor, ceramic disc, 47 mmf, 600 VDCW | C22-47 |
| C108 | Capacitor, ceramic disc, .02 mfd, 600 VDCW | C22-.02 |
| C109 | Capacitor, ceramic disc, 100 mmf, 600 VDCW | C22-100 |
| C301 | Capacitor, tubular, electrolytic, 40 mfd, 350 VDCW | C23-40 |
| C302 | Capacitor, tubular, electrolytic, 40 mfd, 350 VDCW | C23-40 |
| C303 | Capacitor, tubular, electrolytic, 20 mfd, 600 VDCW | C35-20 |
| C304 | Capacitor, tubular, electrolytic, 20 mfd, 450 VDCW | C8-20L |
| C305 | Capacitor, ceramic disc, .02 mfd, 600 VDCW | C22-.02 |
| C306 | Capacitor, ceramic disc, .02 mfd, 600 VDCW | C22-.02 |
| C307 | Capacitor, tubular, electrolytic, 20 mfd, 600 VDCW | C35-20 |
| C308 | Capacitor, ceramic disc, .02 mfd, 600 VDCW | C22-.02 |
| C309 | Capacitor, tubular, electrolytic, 20 mfd, 450 VDCW | C8-20L |
| C310 | Capacitor, ceramic disc, 220 mmf, 600 VDCW | C22-220 |
| C311 | Capacitor, ceramic disc, .02 mfd, 600 VDCW | C22-.02 |
| D1 | Diode, Silicon, 1N482, Transitron | RF14 |
| D2 | Diode, Silicon, 1N482, Transitron | RF14 |
| F1 | Fuse, 1-1/2A, 3AG (110v), Fuse, 1A, 3AG (220v) | FU8-FU7 |
| M | Meter, Panel, 0-200UA | ME15 |
| R101 | Resistor, wirewound, 1 ohm, 1%, 10 w | R34-1 |
| R102 | Resistor, wirewound, 10 ohm, 1%, 10 w | R34-10 |
| R103 | Resistor, wirewound, 100 ohm, 1%, 10 w | R34-100 |
| R104 | Resistor, deposited carbon, 1K, 1%, 1/2 w | R12-1K |
| R105 | Resistor, deposited carbon, 10K, 1%, 1/2 w | R12-10K |
| R106 | Resistor, deposited carbon, 100K, 1%, 1/2 w | R12-100K |
| R107 | Resistor, deposited carbon, 1M, 1%, 1/2 w | R12-1M |
| R108 | Resistor, deposited carbon, 10M, 1%, 1 w | R13-10M |
| R109 | Resistor, deposited carbon, 100M, 1%, 2 w | R14-100M |
| R110 | Resistor, hi-meg, $10^9$ ohm | R20-$10^9$ |

| Circuit Desig. | Description | Part No. |
|---|---|---|
| R111 | Resistor, hi-meg, $10^{10}$ ohm | R20-$10^{10}$ |
| R112 | Resistor, hi-meg, $10^{11}$ ohm | R20-$10^{11}$ |
| R116 | Resistor, deposited carbon, 100M, 1%, 2 w | R14-100M |
| R117 | Resistor, deposited carbon, 1M, 1%, 1/2 w | R12-1M |
| R118 | Resistor, deposited carbon, 1M, 1%, 1/2 w | R12-1M |
| R119 | Resistor, composition, 470 ohm, 5%, 1/2 w | R19-470 |
| R120 | Resistor, deposited carbon, 100K, 1%, 1/2 w | R12-100K |
| R121 | Potentiometer, wirewound, 15K | RP3-15K |
| R122 | Resistor, composition, 47K, 5%, 1/2 w | R19-47K |
| R123 | Resistor, composition, 10M, 10%, 1/2 w | R1-10M |
| R124 | Resistor, deposited carbon, 100 ohm, 1%, 1/2 w | R12-100 |
| R125 | Resistor, deposited carbon, 900 ohm, 1%, 1/2 w | R12-900 |
| R126 | Resistor, deposited carbon, 9K, 1%, 1/2 w | R12-9K |
| R127 | Resistor, deposited carbon, 215K, 1%, 1 w | R13-215K |
| R128 | Resistor, wirewound, 135 ohm, 1%, 1/2 w | R18-10-135 |
| R129 | Resistor, power, 12K, 3%, 25 w | R30-12K |
| R130 | Resistor, deposited carbon, 33.3K, 1%, 1/2 w | R12-33.3K |
| R131 | Resistor, deposited carbon, 20K, 1%, 1/2 w | R12-20K |
| R132 | Resistor, deposited carbon, 5K, 1%, 1/2 w | R12-5K |
| R133 | Resistor, deposited carbon, 5K, 1%, 1/2 w | R12-5K |
| R134 | Resistor, deposited carbon, 5K, 1%, 1/2 w | R12-5K |
| R135 | Resistor, deposited carbon, 5K, 1%, 1/2 w | R12-5K |
| R136 | Resistor, deposited carbon, 5K, 1%, 1/2 w | R12-5K |
| R137 | Resistor, deposited carbon, 5K, 1%, 1/2 w | R12-5K |
| R138 | Resistor, deposited carbon, 20K, 1%, 1/2 w | R12-20K |
| R139 | Resistor, deposited carbon, 1K, 1%, 1/2 w | R12-1K |
| R140 | Resistor, deposited carbon, 200 ohms, 1%, 1/2 w | R12-200 |
| R141 | Resistor, deposited carbon, 1K, 1%, 1/2 w | R12-1K |
| R142 | Resistor, deposited carbon, 10M, 1%, 1 w | R13-10M |
| R143 | Resistor, deposited carbon, 10M, 1%, 1 w | R13-10M |
| R144 | Resistor, composition, 100K, 5%, 1/2 w | R19-100K |
| R145 | Resistor, composition, 100K, 5%, 1/2 w | R19-100K |
| R146 | Resistor, deposited carbon, 100K, 1%, 1/2 w | R12-100K |
| R147 | Resistor, deposited carbon, 1M, 1%, 1/2 w | R12-1M |
| R148 | Resistor, deposited carbon, 1.5M, 1%, 1/2 w | R12-1.5M |
| R149 | Resistor, composition, 330K, 5%, 1/2 w | R19-330K |
| R150 | Resistor, composition, 1K, 5%, 1/2 w | R19-150K |
| R151 | Resistor, composition, 47K, 5%, 1/2 w | R19-47K |
| R152 | Resistor, composition, 100K, 5%, 2 w | R33-120K |
| R153 | Resistor, composition, 390K, 5%, 1/2 w | R19-390K |
| R154 | Resistor, composition, 330K, 5%, 1/2 w | R19-330K |
| R155 | Resistor, wirewound, 30K, 10%, 10 w | R5-30K |

| Circuit Desig. | Description | Part No. |
|---|---|---|
| R156 | Resistor, deposited carbon, 800K, 1%, 1/2 w | R12-800K |
| R157 | Potentiometer, carbon, 500K, 10% | RP7-3 |
| R158 | Resistor, deposited carbon, 20K, 1%, 1/2 w | R12-20K |
| R159 | Resistor, deposited carbon, 70K, 1%, 1/2 w | R12-70K |
| R160 | Potentiometer, wirewound, 5K | RP3-5K |
| R161 | Resistor, deposited carbon, 45.5K, 1%, 1/2 w | R12-45.5K |
| R162 | Resistor, deposited carbon, 136K, 1%, 1/2 w | R12-136K |
| R163 | Resistor, deposited carbon, 319K, 1%, 1/2 w | R12-319K |
| R164 | Resistor, deposited carbon, 6K, 1%, 1/2 w | R12-6K |
| R165 | Resistor, deposited carbon, 7K, 1%, 1/2 w | R12-7K |
| R166 | Resistor, deposited carbon, 2K, 1%, 1/2 w | R12-2K |
| R167 | Resistor, deposited carbon, 700 ohm, 1%, 1/2w | R12-700 |
| R168 | Resistor, deposited carbon, 200 ohms, 1%, 1/2w | R12-200 |
| R169 | Resistor, deposited carbon, 70 ohm, 1%, 1/2w | R12-70 |
| R170 | Resistor, deposited carbon, 20 ohm, 1%, 1/2w | R12-20 |
| R171 | Resistor, deposited carbon, 9.67 ohm, 1%, 1/2w | R12-9.67 |
| R172 | Resistor, composition, 1K, 10%, 1/2 w | R1-1K |
| R173 | Resistor, composition, 2.2K, 10%, 1/2 w | R1-2.2K |
| R174 | Resistor, composition, 4.7K, 10%, 1/2 w | R1-4.7K |
| R175 | Resistor, composition, 10K, 10%, 1/2 w | R1-10K |
| R176 | Resistor, composition, 33K, 10%, 1/2 w | R1-33K |
| R177 | Resistor, deposited carbon, 10K, 1%, 1/2 w | R12-10K |
| R178 | Resistor, deposited carbon, 3K, 1%, 1/2 w | R12-3K |
| R179 | Potentiometer, wirewound, 15K | RP3-15K |
| R180 | Potentiometer, 10K | RP4-10K |
| R181 | Resistor, deposited carbon, 220K, 1%, 1/2 w | R12-220K |
| R182 | Resistor, deposited carbon, 400 ohm, 1%, 1/2w | R12-400 |
| R183 | Resistor, wirewound, 20 ohm, 10%, 3 w | R80-20 |
| R301 | Resistor, composition, 100 ohm, 10%, 1/2 w | R1-100 |
| R302 | Resistor, composition, 100 ohm, 10%, 1/2 w | R1-100 |
| R303 | Resistor, wirewound, 10K, 10%, 10 w | R5-10K |
| R304 | Resistor, composition, 470 ohm, 1%, 2 w | R3-470 |
| R305 | Resistor, composition, 100 ohm, 10%, 1/2 w | R1-100 |
| R306 | Resistor, composition, 1K, 10% 1 w | R2-1K |
| R307 | Resistor, wirewound, 10K, 10%, 10 w | R5-10K |
| R308 | Resistor, composition, 8.2K, 10%, 2 w | R3-8.2K |
| R309 | Resistor, deposited carbon, 3.33M, 1%, 1/2 w | R12-3.33M |
| R310 | Resistor, composition, 750K, 5%, 1/2 w | R19-750K |
| R311 | Resistor, deposited carbon, 2M, 1%, 1/2 w | R12-2M |
| R312 | Resistor, deposited carbon, 680K, 1%, 1/2 w | R12-680K |
| R313 | Resistor, deposited carbon, 2M, 1%, 1/2 w | R12-2M |
| R314 | Potentiometer, carbon, 100K, 3 w | RP15-100K |
| R315 | Resistor, deposited carbon, 700K, 1%, 1/2 w | R12-700K |
| R316 | Resistor, deposited carbon, 2M, 1%, 1/2 w | R12-2M |

| Circuit Desig. | Description | Part No. |
|---|---|---|
| RF301 | Rectifier, selenium, 130V, 65Ma | RF18 |
| RF302 | Rectifier, selenium, 130V, 65Ma | RF18 |
| RF303 | Rectifier, selenium, 130V, 65Ma | RF18 |
| RF304 | Rectifier, selenium, 130V, 65Ma | RF18 |
| RF305 | Rectifier, selenium, 130V, 65Ma | RF18 |
| RF306 | Rectifier, selenium, 130V, 65Ma | RF18 |
| RF307 | Rectifier, selenium, 130V, 65Ma | RF18 |
| RF308 | Rectifier, selenium, 130V, 65Ma | RF18 |
| RF309 | Rectifier, selenium, 130V, 65Ma | RF18 |
| RF310 | Rectifier, selenium, 130V, 65Ma | RF18 |
| SW1 | Range switch 23 position | SW-46 |
| SW2 | Slide switch, SPDT | SW-45 |
| SW3 | Operate switch, 3 position | SW-67-A |
| SW4 | Coarse-balance switch, 7 position | SW-93 |
| SW5 | Volt switch 9 position | SW-48 |
| SW6 | Slide switch, DPDT | SW-45 |
| SW7 | Meter switch, 5 position | SW-64 |
| | Power transformer, (Model 610A) | TR-23 |
| | Power Transformer, (Model 610R) | TR-57 |
| | Pilot Lamps 6.3 v, 0.15 amp. miniature bayonet base G. E. type #47 | PL-4 |
| V1 | Vacuum tube, type 5886* | EV-5886-5 |
| V2 | Vacuum tube, type 5886* | EV-5886-5 |
| V3 | Vacuum tube, type EF86 | EV-EF86 |
| V4 | Vacuum tube, type EF86 | EV-EF86 |
| V5 | Vacuum tube, type 6BH8 | EV-6BH8 |
| V6 | Vacuum tube, type 12AX7 | EV-12AX7 |
| V7 | Vacuum tube, type 12AX7 | EV-12AX7 |
| V8 | Vacuum tube, type 12B4A | EV-12B4A |
| V9 | Vacuum tube, type 0B2 | EV-0B2 |
| V10 | Vacuum tube, type 0G3 | EV-0G3 |
| V11 | Vacuum tube, type 0A2 | EV-0A2 |

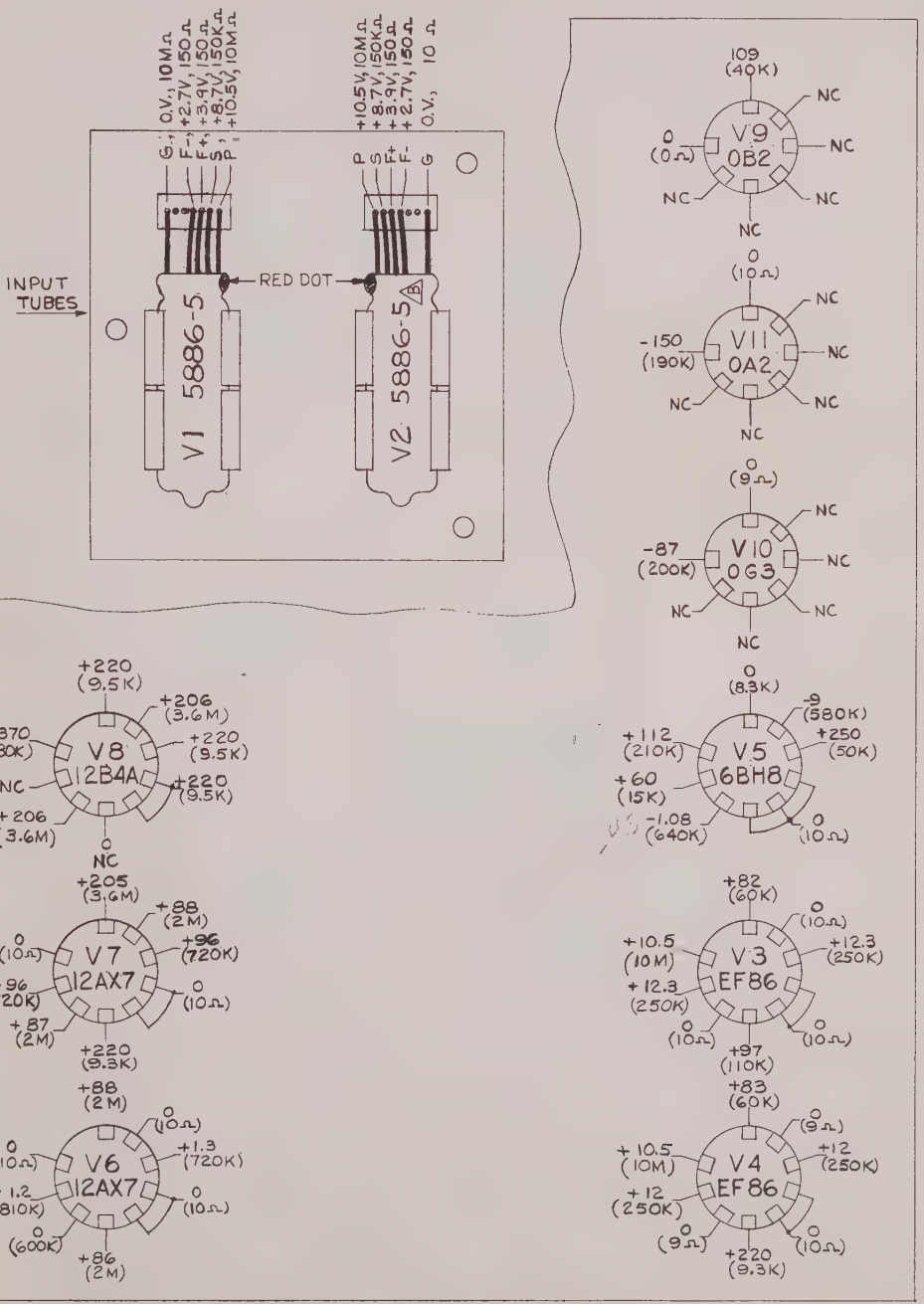
*V1 and V2 are matched tubes, and should be ordered from Keithley Instruments as "EV-5886 matched tubes for Model 610A Electrometer".

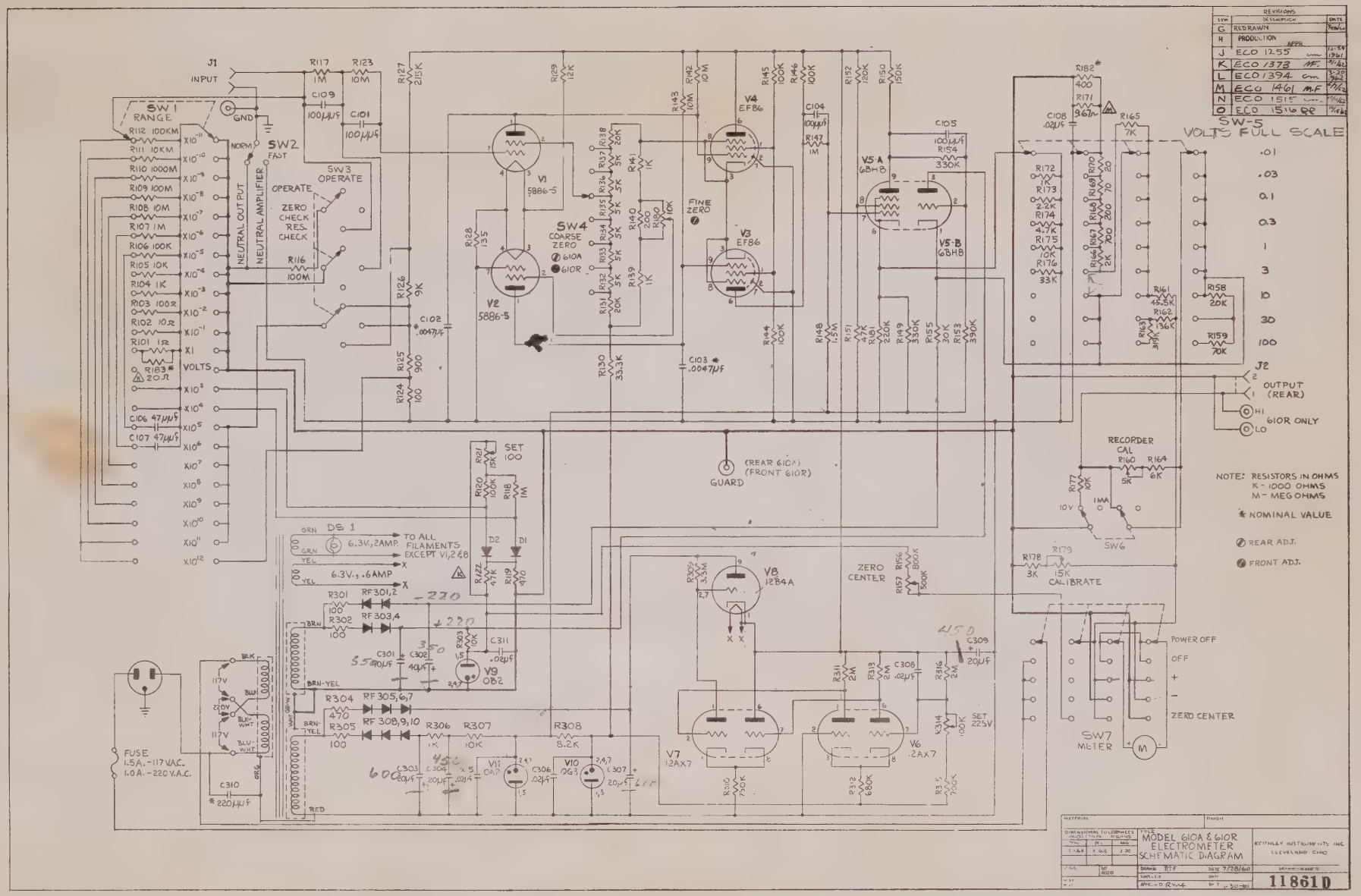
| | | | |
|---|---|---|---|
| B | 1768 | 6/8/62 | LS |
| A | 495 | 11/10/59 | 11-11-59 RMM |

DR 11968 -C

# MODEL 610A
# VOLTAGE AND RESISTANCE CHART

MEASUREMENTS MADE FROM TUBE PIN TO CHASSIS GROUND WITH CONTROLS SET AS FOLLOWS; "OPERATE" SW. - ZERO CHECK POSITION
MULTIPLIER - .01 POSITION
METER SW. - + POSITION
READINGS TAKEN WITH 11 MEGOHM INPUT RESISTANCE VTVM.
ALL READINGS ARE APPROXIMATE. RESISTANCES ARE GIVEN IN OHMS.
K = 1000, M = MEGOHMS.




REVISIONS
LTR DESCRIPTION DATE APPR.
G REDRAWN
H PRODUCTION
J ECO 1255
K ECO 1373
L ECO 1394
M ECO 1461
N ECO 1515
O ECO 1516
SW1 RANGE
SW2 FAST
SW3 OPERATE
SW4 COARSE ZERO
SW5 VOLTS FULL SCALE
SW6
SW7 METER
J1 INPUT
J2 OUTPUT (REAR)
GUARD
FINE ZERO
ZERO CENTER
CALIBRATE
RECORDER CAL
NOTE: RESISTORS IN OHMS K - 1000 OHMS M - MEG OHMS
* NOMINAL VALUE
REAR ADJ.
FRONT ADJ.
MODEL 610A & 610R ELECTROMETER SCHEMATIC DIAGRAM
KEITHLEY INSTRUMENTS INC CLEVELAND OHIO
118610

## WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof (except tubes and batteries) which, within a year after shipment, proves defective upon examination. We will pay domestic surface freight costs.

To exercise this warranty, call your local field representative or the plant directly, DDD 216-795-2666. You will be given assistance and shipping instructions.

## REPAIRS AND RECALIBRATION

Keithley Instruments maintains a complete repair service and standards laboratory in Cleveland, and has authorized field repair facilities in Los Angeles and Albuquerque.

To insure prompt repair or recalibration service, please contact your local field representative, or the plant directly, before returning the instrument.

Estimates for repairs, normal recalibrations, and calibrations traceable to the National Bureau of Standards are available upon request.

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